

Patent Claims:

1. Electrohydraulic brake system for motor vehicles which can be operated in a 'brake-by-wire' mode of operation, comprising:

- a master cylinder (1) to which wheel brake cylinders can be connected,
- a first piston (2) which is coupled to a brake pedal (3),
- a second piston (4) which actuates the master cylinder (1),
- a third piston (5) which can be operated by the first piston (2),

with at least one brake pedal characteristics simulation device (6, 7) exerting a simulator force being provided between the first (2) and the third piston (5) and imparting a comfortable pedal feel to the operator in a by-wire mode of operation, and all three pistons (2, 4, 5) and the travel simulator device are arranged in a housing (8),

- a hydraulic pressure source (9) and
- a valve device (10) operable by the third piston (5) for reducing the pressure of the pressure source (9)

to a value used for application of the second piston (4),

and the second (4) and the third piston (5) are isolated from each other by a space (11) in such a fashion that the third piston (5) is acted upon by the pressure that acts on the second piston (4) in the direction opposite to the direction of application of the second piston (4),

characterized in that both end surfaces of a valve member (13) of the valve device (10) are exposed to the effect of the pressure that prevails in the space (11).

2. Brake system as claimed in claim 1,
characterized in that an end surface of the valve member (13) is exposed to the effect of the pressure prevailing in the space (11) by way of a hydraulic connection (12) provided in the housing (8).
3. Brake system as claimed in claim 1,
characterized in that the two end surfaces of the valve member (13) communicate with each other through a longitudinal bore in the valve member (13).
4. Brake system as claimed in any one of claims 1 to 3,
characterized in that the moving directions of the valve member (13) and the third piston (5) upon actuation of the valve device (10) by the third piston (5) are identical.

5. Brake system as claimed in any one of claims 1 to 4, characterized in that that valve member (13) can be actuated directly by the third piston (5).
6. Brake system as claimed in claim 5, characterized in that the third piston (5) includes a radial projection (14) which cooperates in a force-transmitting fashion with the end surface of the valve member (13) facing the space (11).
7. Brake system as claimed in any one of claims 1 to 4, characterized in that the valve member (13) is operable by a lever or cross bar (31) which cooperates with the third piston (5), is mounted in the housing (8) and arranged preferably vertically to the longitudinal axis of the third piston (5).
8. Brake system as claimed in any one of claims 1 to 7, characterized in that the hydraulic pressure source (9) is formed of a high-pressure accumulator (19) which can be charged by a motor-and-pump assembly (20).
9. Brake system as claimed in any one of claims 1 to 8, characterized in that a second valve device (15, 16) that is electrically operable by means of an electronic control unit is used to influence the pressure that is to be introduced into the space (11) and is integrated in the housing (8).

10. Brake system as claimed in any one of claims 1 to 9, characterized in that a pressure sensor (39) is provided to monitor the charging condition of the high-pressure accumulator (19), whose output signal is sent to the electronic control unit and which is integrated in the housing (8) or form-lockingly connected to it.
11. Brake system as claimed in any one of claims 1 to 10, characterized in that a pressure sensor (18) is provided to sense the pressure that prevails in the space (18), whose output signal is sent to the electronic control unit and which is integrated in the housing (8) or form-lockingly connected to it.
12. Brake system as claimed in any one of claims 8 to 11, characterized in that the high-pressure accumulator (19) is arranged directly at the housing (8), and a hydraulic connection (23) between the pressure side of a pump (27) of the motor-and-pump assembly (20) and the high-pressure accumulator (19) is formed by at least one bore provided in the housing (8).
13. Brake system as claimed in claim 12, characterized in that a non-return valve (24) opening towards the high-pressure accumulator (19) is inserted into the hydraulic connection (23).

14. Brake system as claimed in any one of the preceding claims,
characterized in that an electronic control or regulation unit (28) of an anti-lock system (ABS) is connected to the master brake cylinder (1).
15. Brake system as claimed in claim 14,
characterized in that the electrohydraulic control or regulation unit (28) operates according to the return delivery principle and includes a device (30) for the return delivery of excessive pressure fluid volume into the master brake cylinder (1).
16. Brake system as claimed in any one of the preceding claims 1 to 7 and 9 to 15,
characterized in that the motor-and-pump assembly (20) is integrated into the electrohydraulic control or regulation unit (28).
17. Brake system as claimed in claim 16,
characterized in that pressure fluid under atmospheric pressure is supplied to the pump (27) through a first hydraulic connection (50) arranged between the housing (8) and the control or regulation unit (28), and the pressure fluid discharged under high pressure from the pump (27) is conducted through a second hydraulic connection (51) being arranged between the control or regulation unit

(28) and the housing (8) to a portion (52) of the hydraulic connection (23) that extends within the housing (8) and leads to the high-pressure accumulator (19).

18. Brake system as claimed in claim 17, characterized in that a non-return valve opening to the high-pressure accumulator (19) is inserted within the portion (52).
19. Brake system as claimed in claim 17, characterized in that inserted within the portion (52) is an electrically controllable valve (25), preferably a two-way/two-position directional control valve, which fulfils the function of a non-return valve opening towards the high-pressure accumulator (19) in a first switch position and opens the hydraulic connection (51) in a second switch position.
20. Brake system as claimed in claim 15, characterized in that the device (30) for the return delivery of excessive pressure fluid volume can be driven by the pressure generated by the motor-and-pump assembly (9).
21. Brake system as claimed in claim 15, characterized in that the device (30) for the return delivery of excessive pressure fluid volume can be driven both by the pressure generated by the motor-and-pump assembly (20) and by the

pressure prevailing in the high-pressure accumulator (19).

22. Brake system as claimed in claim 20 or 21, characterized in that the device (30) is provided by at least two low-pressure accumulators (30a,b; 40a,b) which alternately take up prevailing pressure fluid volume or displace the prevailing pressure fluid volume under the effect of the driving pressure in the sense of a return delivery.
23. Brake system as claimed in any one of the preceding claims 20 to 22, characterized in that the motor-and-pump assembly (20) or the high-pressure accumulator (19) in conjunction with the electrically controllable valve (25) cooperates with a valve device (29) which alternately provides the driving pressure or the atmospheric pressure for the low-pressure accumulators (30a,b; 40a,b).
24. Brake system as claimed in claim 23, characterized in that the valve device (29) is integrated into the electrohydraulic control or regulation unit (28).
25. Brake system as claimed in any one of the preceding claims, characterized in that the brake pedal characteristics simulation device comprises at least one elastic element (6, 7) which exerts a 'spring

force' component of the simulator force that depends on the relative travel between the first (2) and the third piston (5).

26. Brake system as claimed in claims 25, characterized in that the brake pedal characteristics simulation device comprises at least one damping device which exerts a 'damping force' component of the simulator force that depends on the relative speed between the first (2) and the third piston (5).
27. Brake system as claimed in claim 25 or 26, characterized in that the brake pedal characteristics simulation device (6, 7) comprises at least one of the components 'steel spring, elastomeric body, and frictional connection' exerting the simulator force.
28. Brake system as claimed in any one of claims 25 to 27, characterized in that the brake pedal characteristics simulation device (6, 7) can be blocked in such a manner that it prevents in the blocked condition a movement of the first piston (2) relative to the third piston (5) in the actuating direction which exceeds the existing piston positions.

29. Brake system as claimed in claim 28,
characterized in that the brake pedal characteristics simulation device (6, 7) is blocked in dependence on the relative travel of the third piston (5) with respect to the housing (8).
30. Brake system as claimed in claim 29,
characterized in that the brake pedal characteristics simulation device cooperates with a hydraulic chamber (21) that is limited by the first piston (2) in the third piston (5) and is in connection to an unpressurized pressure fluid supply reservoir (22) through another hydraulic connection (50) and which can be closed by a relative movement of the third piston (5) relative to the housing (8).
31. Brake system as claimed in any one of claims 25 to 27,
characterized in that the brake pedal characteristics simulation device (6, 7) can be blocked in such a manner that it prevents in the blocked condition a movement of the first piston (2) relative to the second piston (4) in the actuating direction which exceeds the existing piston positions.
32. Brake system as claimed in claim 29,
characterized in that the brake pedal characteristics simulation device cooperates with a hydraulic chamber (42, 43, 44, 45) that is limited by the first piston (2) in the third piston (5) and is

in connection to the unpressurized pressure fluid supply reservoir (22) and which can be closed by a relative movement of the third piston (5) relative to the housing (8).

33. Brake system as claimed in any one of claims 30 to 32,
characterized in that damping or at least part of the damping of the brake pedal characteristics simulation device (6, 7) is achieved by a corresponding dimensioning of a hydraulic connection (50) between the hydraulic chamber (42, 43, 44, 45) and the unpressurized pressure fluid supply reservoir (22).
34. Brake system as claimed in claim 33,
characterized in that damping of the brake pedal characteristics simulation device (6, 7) is achieved by a hydraulic damping device inserted into the hydraulic connection (50).
35. Brake system as claimed in claim 34,
characterized in that the damping device comprises hydraulic orifices and includes a damping characteristics which depends on the direction of flow.

36. Brake system as claimed in any one of claims 27 to 35,
characterized in that the components exerting the simulator force are arranged in each case either outside ('dry') or inside ('wet') the hydraulic chamber (21).